Tactical Ocean Data System (TODS)
Modeling, Sensing and Forecasting Ocean Optical Products for Navy Operations

($K)	FY11	FY12	FY13	FY14	Total
TODS	300	150	235	215	900
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- FY13 Deliveries
  - BioCast v1.0 with VTR delivered 20DEC13.
  - BathyGen v1.0 software delivered 20DEC13.

- Technical Accomplishments
  - Modified 3D optical forecast software BioCast v1.0 to improve numerical stability in turbulent areas.
  - BathyGen v1.0 software developed to allow operational center to produce consistent bathymetry
    files on the same grid (satellite) required as input for the TODS components: (1) 3D Optical Forecast
    software BioCast v1.0 (netCDF) and (2) future transition 3D Optical Generator - 3DOG (HDF).
  - Completed integration of the 3D Optical Generator (3DOG) into TODS and validation underway
    (Future Transition Q3FY14).
  - Implemented a much more efficient evolutionary algorithm in the glider optimization software
    (Frontline Solver SDK) to get more accurate results with significantly less processing time. This set of
    software is used to tune the 3D optical volume (3DOG) coefficients based on insitu glider profiles
    and MODIS satellite data.
  - Modified EODES AOS24 system performance software (C++) to handle I/O of NRL 3D optical volume

- Technical & Financial Issues Encountered & Task Setbacks
  - Encountered and successfully addressed stability issues in BioCast v1.0 in
    turbulent areas.
  - Missed opportunities for Navy Exercise participation due to assets (Optics Gliders,
    AQS24, etc.) being pulled and funding cuts.
  - Spiral development between two projects, Navy ocean color satellite
    processing project (AOPS) and TODS, transitioning to same operational
    group.

- Schedule Slips Encountered (as compared to Final FY13 DD 1498)
  - BioCast v1.0 transition and VTR were delayed 8 months (Delivered Q1FY14). Minor modifications to VTR possible. OpTest at NAVO will start soon.
    - Needed further evaluation and validation in a Navy exercise (Trident Warrior July 2013)
  - 3D Optical Generator (3DOG) delayed 3 months (Q3FY14).
    - Needed optics glider data collected during Trident Warrior 2013 for

| $235K (FY13)	**30-Nov-13**
PI Expenditure	$?K (?%)
PMW 120 Expenditure	$?K (?%)

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- Transition Path & Way Ahead:
  - Future transitions of TODS components BioCast v2.0, 3D Optical Generator (3DOG) v2.0, new Littoral Sediments and Optics Model (LSOM) and new AQS20 System Performance Surfaces will reside with NAVOCEANO NP33
  - BioCast v1.0 validation / VTR delivered to NAVO Q1FY14. 3D Optical Generator (3DOG) transition/VTR currently on schedule for Q3FY14. Upgrades to BioCast (v2.0) for enhanced 3D optical forecasting scheduled for Q3FY15. Upgrade to EODES AQS laser imaging system performance software to support the AQS-20 will need to be done along with initial integration of a 3D sediment resuspension model (LSOM) component by Q4FY15 followed by testing and merging into the 3DOG software (v2.0) in FY16 - (FY15 1498).
  - This task will be completed in Q4FY16 with full TODS capability to support MIW, ASW and SpecOps with forecast 3D optics (with new bottom sediment resuspension) and performance surfaces for (AQS-20/24).
  - No transition issues currently perceived.
  - Transition plan status: FY13 TP exists and FY14 TP is in progress.

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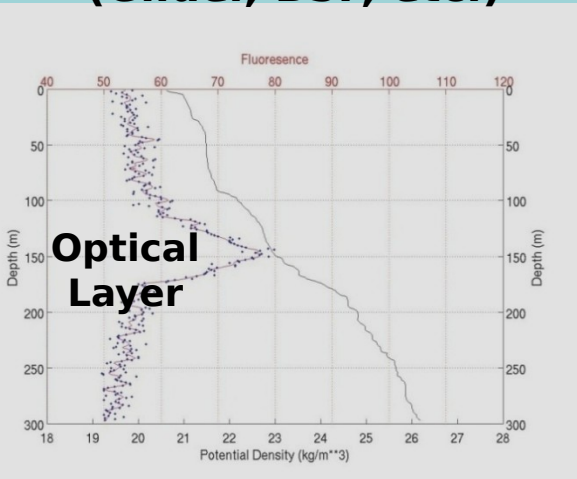
- PI comments:
  - BioCast v1.0 24 hour 3D forecasts outperformed OpCast v2.0 2D forecast as compared to next day's satellite optical product and persistence.
  - Both systems BioCast v1.0 and 3DOG v1.0 performed well during operational assessment during Trident Warrior 2013.
  - New improvement to glider optimization (evolutionary solver – Linux API upgrade) performed very well during Trident Warrior 2013 producing better coefficients in less time for the 3D Optical Generator (3DOG) component.
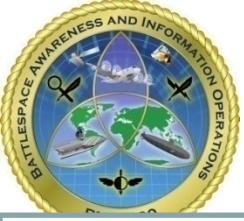
TODS: Fusion of Glider Profiles, Satellite and Numerical Models to support AQS24 Operations

Vertical Optical Profiles (Glider, BSP, etc.)

Optical Layer

Nowcast / Forecast Satellite Optics

Nowcast / Forecast Circulation Models

Depth Layer Info (MLD,iMLD)
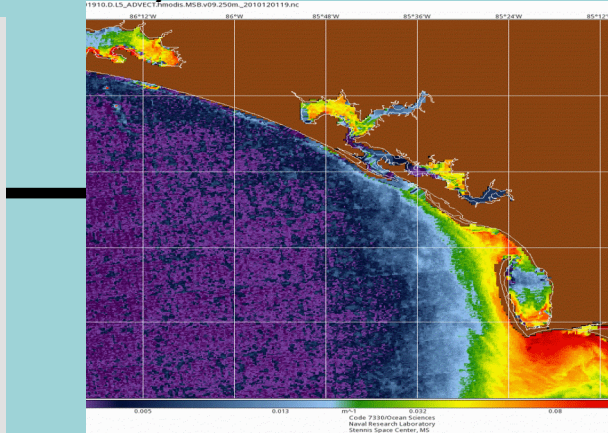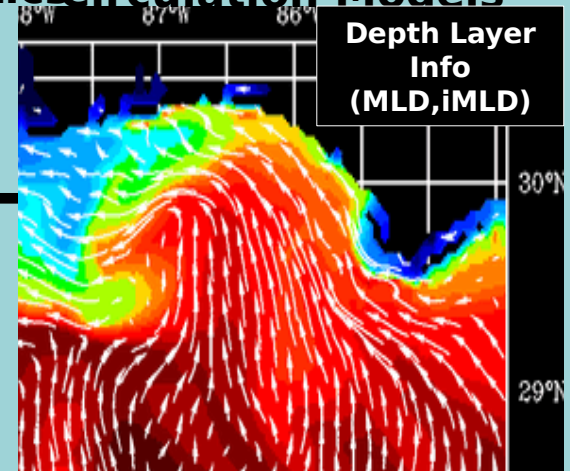
Insitu Optics Used for Tuning Coefficients in 3D Optical

Model coefficients define the relationship between the surface satellite optics, model physics (MLD,IMLD), 1% light level, and the

Optical Volume & 3D Diver Visibility

EODES

Nowcast/Forecast Performance Surface
Image Quality & Optimal System Towing Altitude
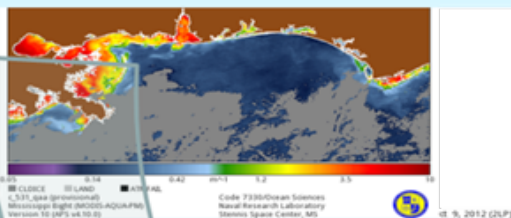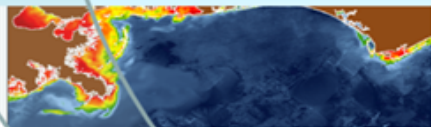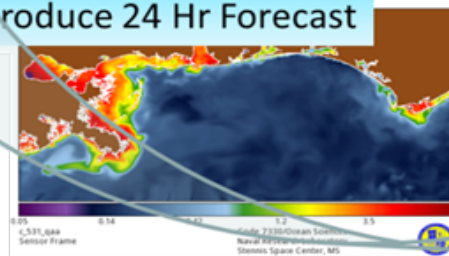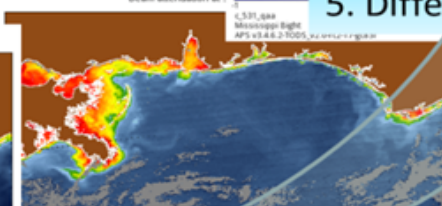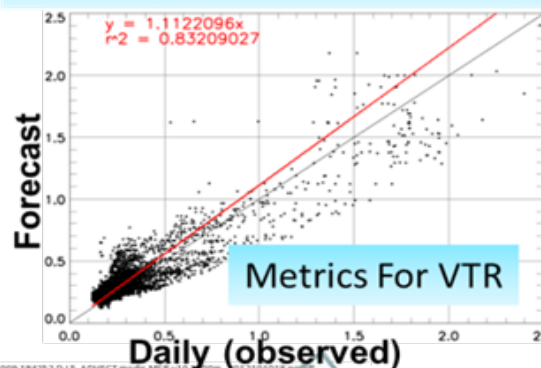
Figure – BioCast Validation procedure. Today's image (of any product, shown here is c 531nm) is obtained from the satellite. An initialization field is created, filling in gaps in coverage. The optical data initialization field is input into BioCast with the NCOM model forecast. BioCast advects the bio-optical property with respect to the predicted currents and ADR to produce a 24 hour forecast. This forecast is then compared to the data derived from the next day's image and a difference field is generated showing the difference between the measured and forecast. Statistics are generated providing metrics for analysis.
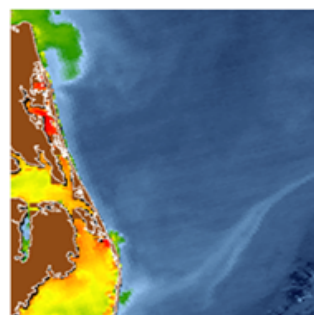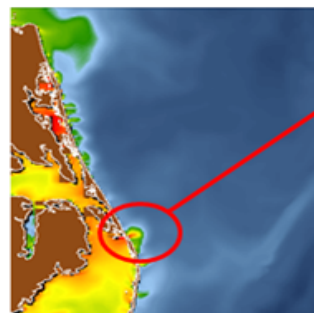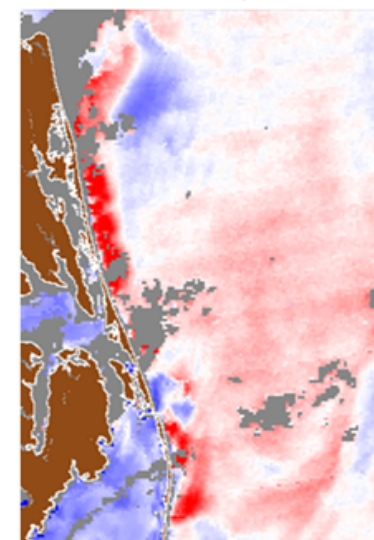
Figure - Example of BioCast processing for Chesapeake Bay, Virginia during the Trident Warrior exercise using the MODIS satellite product for the beam attenuation (proxy for turbidity) coupled with the currents derived from the NCOM, BioCast enables the currents to advect the turbidity pixel information, generating a picture of future turbidity distribution. Differencing the BioCast product from the actual next day's image provides insight into the uncertainty of the BioCast model.

10 Month Mean Forecast Statistics
Beam Attenuation Coefficient (c @531nm)
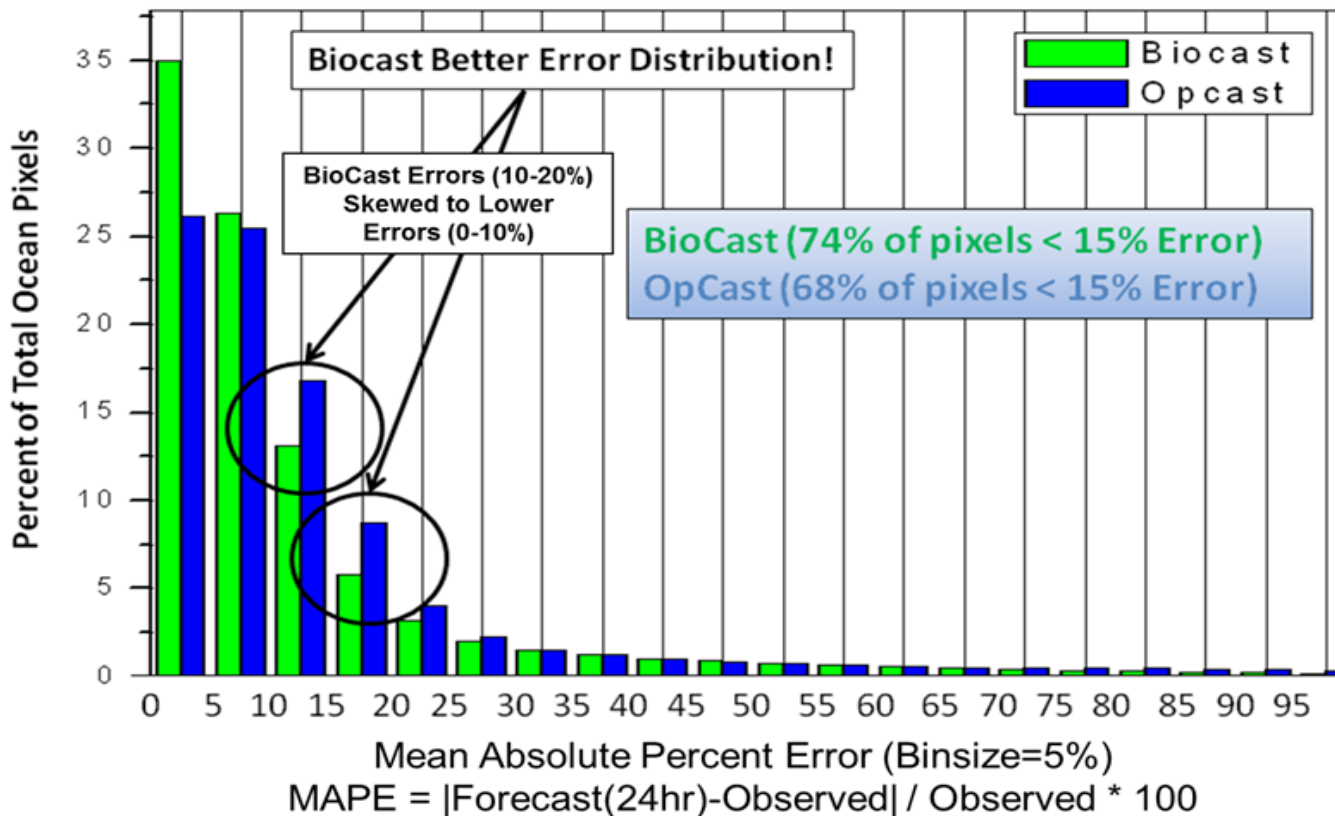
Frequency Distribution of Errors

Figure shows the distribution of the MAPE for BioCast (green) and OpCast (blue) as a function of the percent total ocean pixels, for BioCast 35% of the pixels have a mean absolute percent error from 0-4.9%. Accumulating the errors for BioCast shows that for 74% of the pixels in the forecast image, the error is less than 15% where the error of less than 15% for OpCast is 68%. The overall BioCast improvement is seen in 70% of the total pixels.
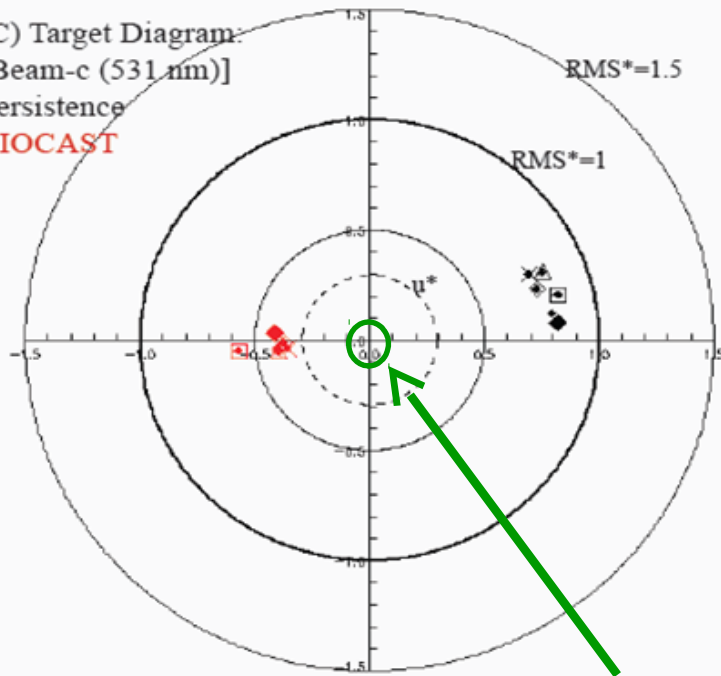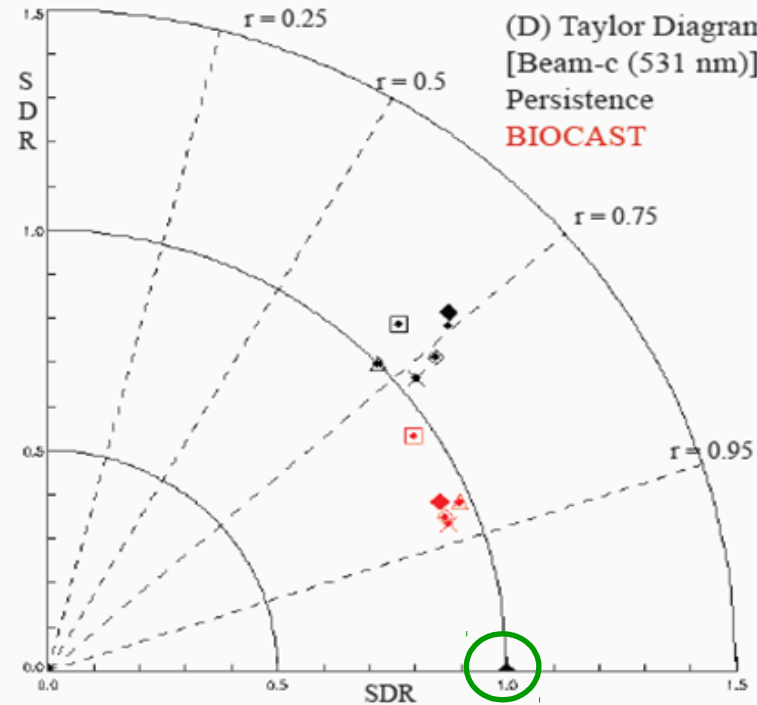
(C) Target Diagram: [Beam-c (531 nm)] Persistence BIOCAST

RMS*=1.5

RMS*=1

u*

(D) Taylor Diagram: [Beam-c (531 nm)] Persistence BIOCAST

r = 0.25

r = 0.5

r = 0.75

r = 0.95

S D R

SDR

Perfect

Perfect

Range from Shoreline: ⊡ 10 km, ▲ 30 km, ✕ 60 km, ◆ 109 km, ♦ 209 km, ◆ 249 km

Range	10 km	30 km	60 km	109 km	209 km	249 km
C (531 nm) MAD Persist. (m^{-1}) x 10^{-2}	29.80	17.17	10.95	8.37	6.57	5.93
C (531 nm) MAD BIOCAST (m^{-1}) x 10^{-2}	17.80	8.00	4.88	3.78	3.08	2.76
BIOCAST-C (531 nm) Difference Reduction (%)	40.3	53.4	55.4	54.8	53.1	53.5
Horizontal Diver Visibility MAD Persistence (m)	2.30	3.98	4.13	4.32	4.29	4.26
Horizontal Diver Visibility MAD BIOCAST (m)	1.50	1.63	1.73	1.73	2.04	1.97
BIOCAST-Diver Vis. Difference Reduction (%)	34.8	59.0	58.1	60.0	52.4	53.8
N (number of comparisons) =	2532	11046	23039	35757	54110	65337